Traveling-Wave Maser, Closed Cycle Refrigerator Automation

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Rationale, functional requirements, implementation guidelines, project organization, high level hardware and software design, and component selection are presented for the maser system automation project.

I. Introduction

At the present time all traveling-wave maser and closed-cycle refrigerator system (TWM-CCR) and their power supply and helium compressor assemblies are operated manually. Many man-hours are required of highly trained and experienced operators, resulting in high operator cost. Of greater importance are the problems of unpredictable failure and long downtimes. Since field performance is not monitored, system degradation is detected only when it has progressed to the point of catastrophic failure. Without the aid of performance histories, failure diagnosis is arduous and slow.

Rationale and functional requirements for the TWM-CCR Automation project are the following: (1) to improve reliability and reduce downtime by providing unattended monitor and control, alarm and fault location, failure prediction and self-corrective action; (2) to reduce operator cost by providing automatic tuning and cooldown procedures; and (3) to improve system operations and development by providing the needed engineering data.

This project is being implemented in phases. In Phase I existing technologies are evaluated, functional requirements defined, high-level plans developed, and component elements identified and procured. In Phase II the hardware is integrated, and the monitor and control functions demonstrated. In Phase III algorithms are developed for logging engineering data, performing system diagnostics, providing alarm status and fault location, and performing automated cooldown, tuning, and self-corrective procedures. This report outlines the efforts at the end of Phase I.

II. System Design and Guidelines for Implementation

Before defining the project organization and guidelines, an extensive review of existing technologies and commercial products was made. To date only one maser has been partially automated, the dual channel S-band maser in operation at the Arecibo Observatory, which was designed and implemented by the Receiver Development Group of Cornell University for the National Astronomy and Ionosphere Center. The system was reviewed in detail, and extensive use has been made of the consulting services of the Resident Support Specialist for that project. Out of this review and the study of presently available commercial products have emerged the following guidelines for implementation.

(1) Components and subsystems are now commercially available so that the design and fabrication of custom maser-controller interfaces are neither necessary, desir-

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able, nor cost effective. With the exception of three specialized subsystems (the TWM pumps, RF monitoring assemblies, and the CCR reserve capacity measuring assembly, which are being designed and fabricated at JPL), all sensors and interfaces are selected from readily available commercial products.

(2) Modification to the existing TWM-CCR configuration should be avoided when possible. This is to minimize the effects on the nonautomated operation of the system, to facilitate documentation and maintenance, and to facilitate the automation of other masers in the DSN. To this end, sensors and interfaces are attached to the system as external modules when possible.

(3) Distributed processing should be used when possible to facilitate the communication between the physically separated subsystems and to isolate and modularize functions. Therefore each major subsystem, the TWM-CCR, the system power supplies, and the helium compressor, will have a dedicated microprocessor-based single board providing the analog and digital I/O and the communication between that subsystem and the maser system controller.

(4) Common software and structured programming techniques should be used as much as possible to reduce software development time, maintenance effort, and documentation.

A block diagram of the system hardware is shown in Fig. 1. A discussion of the system hardware and software is given in the next section.

III. Hardware and Software Implementation

A list of sensors is given in Table 1. These sensors are used to monitor the following parameters in each assembly.

(1) In the TWM-CCR assembly: temperatures of the 4, 15, and 70 kelvin stages; magnetic field; magnet current and charge rate; superconducting switch; refrigerator reserve capacity and drive unit frequency; microwave pump source bias, tune, and modulation voltages, and power; and maser RF gain versus frequency.

(2) In the power supply assembly: system voltages; vacion pump controls, current, and voltage.

(3) In the helium compressor: the pressures at the Joule-Thompson (J-T) supply and return; the pressures at the helium supply, refrigerator supply line and return, and the compressor storage tank and oil separator; the J-T mass flow; the temperatures of the first and second stages of the compressor, of the gas return, and of ambient; the voltages, currents, and power to the three phase motor; and supply voltages. Switch closures will indicate the on/off status of the compressor and refrigerator, as well as alarm conditions in the compressor temperature and pressure and in the airflow fan.

Analog signals control the superconducting magnet charge rate, magnetic field profile currents, microwave source pump tuning and modulation. Digital signals control system power supplies, vacion pump controls, compressor start, CCR start, compressor-CCR stop, and solenoid valves on the helium supply line, refrigerator return, J-T return and vent, storage tank, and the blowdown line. Switches and indicator lamps provide visual alarm indicators as well as a means of communication between field personnel and remote operations. A series of open or closed contacts provide a unique binary code for each maser system so that in the future many maser systems may be remotely identified and monitored. Sufficient extra terminal strip junctions and cabling are provided so that sensors and controls can be conveniently added or reconfigured.

All sensors and control elements connect directly to a commercial microprocessor-based interface, which contains its own power supply, and provides signal conditioning and linearization, excitation signals for the RTD and strain gauges, 13-bit integrating A/D, unit conversion, limit checking and alarm status, high common mode voltage isolation (1000 V peak) and high common mode rejection (160 dB). This interface, manufactured by Analog Devices (uMAC4000), is capable of storing 48 analog and 32 digital inputs in RAM at the rate of 15 channels/sec and can provide up to 32 digital outputs. Communication between this interface and the maser system controller is by RS-232C lines in ASCII format at speeds up to 9600 baud and is controlled by high level commands.

The maser system controller is a Multibus-based system in a configuration being standardized for controllers in the network consolidation project (NCP). Boards used include: CPU – BLC 80/204; disk controller – BLC 8201; 4-channel serial interface – iSBC 534; 64k RAM – BLC 064; and the JPL Quad Standard Interface.

Common software for these controllers includes:

(1) A disk-based operating system, which enables programs to be compiled, debugged, placed in ROM, and executed within the target controller.

(2) A real-time, priority-based, multitasking, multiprogramming executive (EMX) which occupies 1.4K of memory.

(3) A maintenance terminal handler (MTH), which uses a menu-prompting protocol to display system status,

modify the database, and perform subsystem operations.

(4) A driver for a Racah-Vadic modem to provide for remote operating and maintenance.

All coding is in PL/M compatible with both 8080 and 8086 CPU families.

IV. Plans

Maser system controllers are now being implemented at JPL using existing R/D compressor and X-band TWM-CCR assemblies. Demonstration of all proposed monitor and control functions is planned for next year, and the development of automated procedures and demonstration of the entire system at DDS 13 in the year to follow.

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Table 1. Sensors used to monitor maser system performance

Measurement	Sensor	Range
Pressure	Viatran, series 218	0-25, 0-500, 0-3000 psig
Mass flow	Hasting, series AFSC	0-10k, 0-50k SCCM
Temperature	RTD	200-800 K
	Analog Devices, AD590	220-420 K
	Lake Shore Cryotronics, silicon diodes DT-500-DRC	1-300 K
AC voltage	Ohio Semitronics, series VT	0-150, 0-575 VAC
AC current	Ohio Semitronics, series CT	0-20 A
AC power	Ohio Semitronics, PC5-18	0-14.4 kW
Magnetic field	Siemens, magnetoresistors, FP30L100J	0-12 kG at 4.5 K
RF power	Hewlett-Packard, PDR	

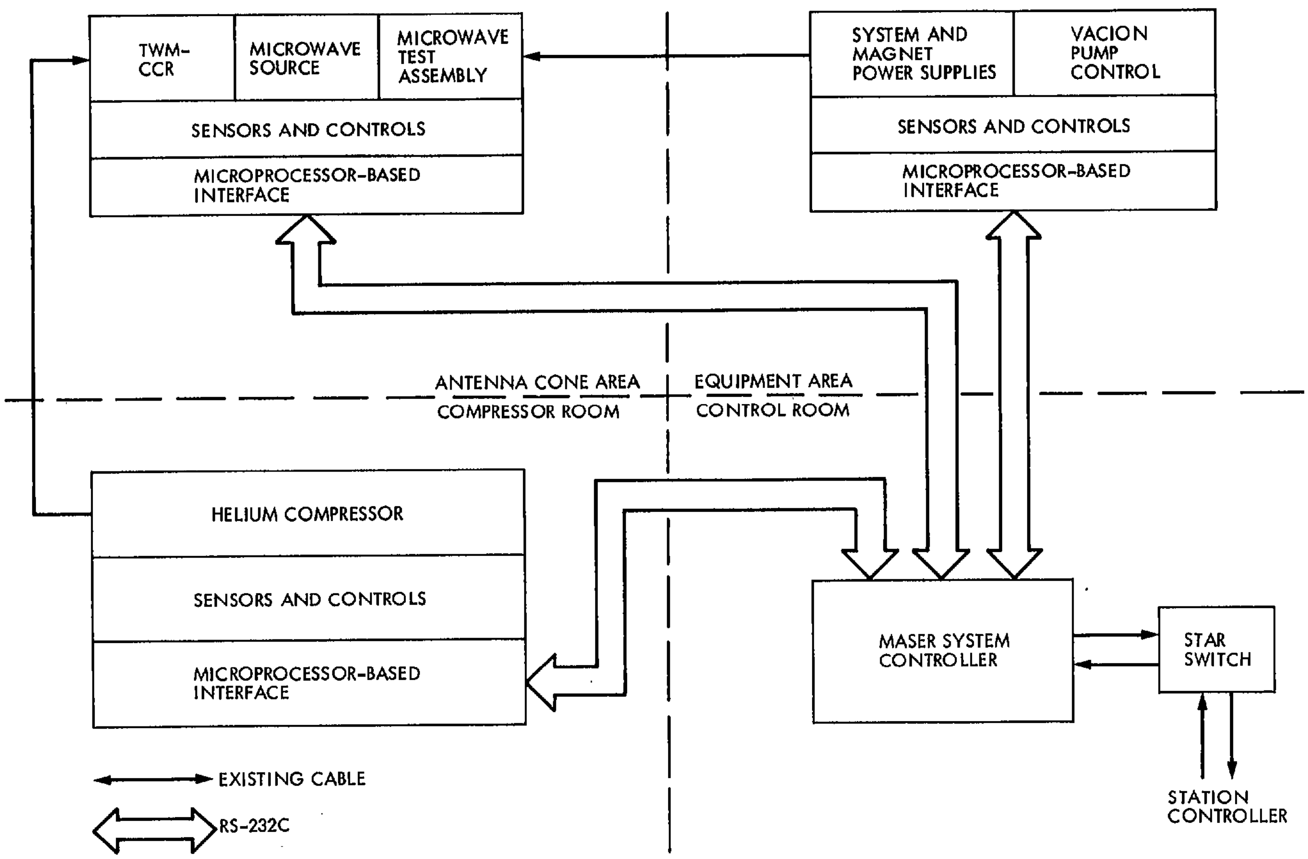

Fig. 1. Simplified block diagram of maser system automation hardware. Sensors, controls, and interfaces are externally appended to existing assemblies with minimal effect on the manual mode of operation of the system